# 2003 International ALARA Symposium

## Fuel decontamination at Ringhals 1 with the new decontamination process ICEDEC™

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# ICEDEC™

Ice decontamination

- Fuel decontamination by abrasion with ice particles

# Background

- Many reactors had average radiation levels far above recommendations
  - ↗Mandose reduction required
- Many ALARA remedies already taken

⇒

New approach needed!

# Background *contd*.

- Attack the origin of the radiation - the fuel crud
  - ↗The main part of the radiation originates from cobalt
    - –Co-60 worst nuclide

# Development of the fuel decontamination technique ICEDEC™

- Developed by Westinghouse Atom in co-operation with Ringhals 1
- Feasibility studies 1995-1997
- Loop performance tests 1998
- Fuel integrity tests 1998
- Pilot plant tests with synthetic loose crud 1998
- Evaluation and preparation for full-scale testing 1999-2000

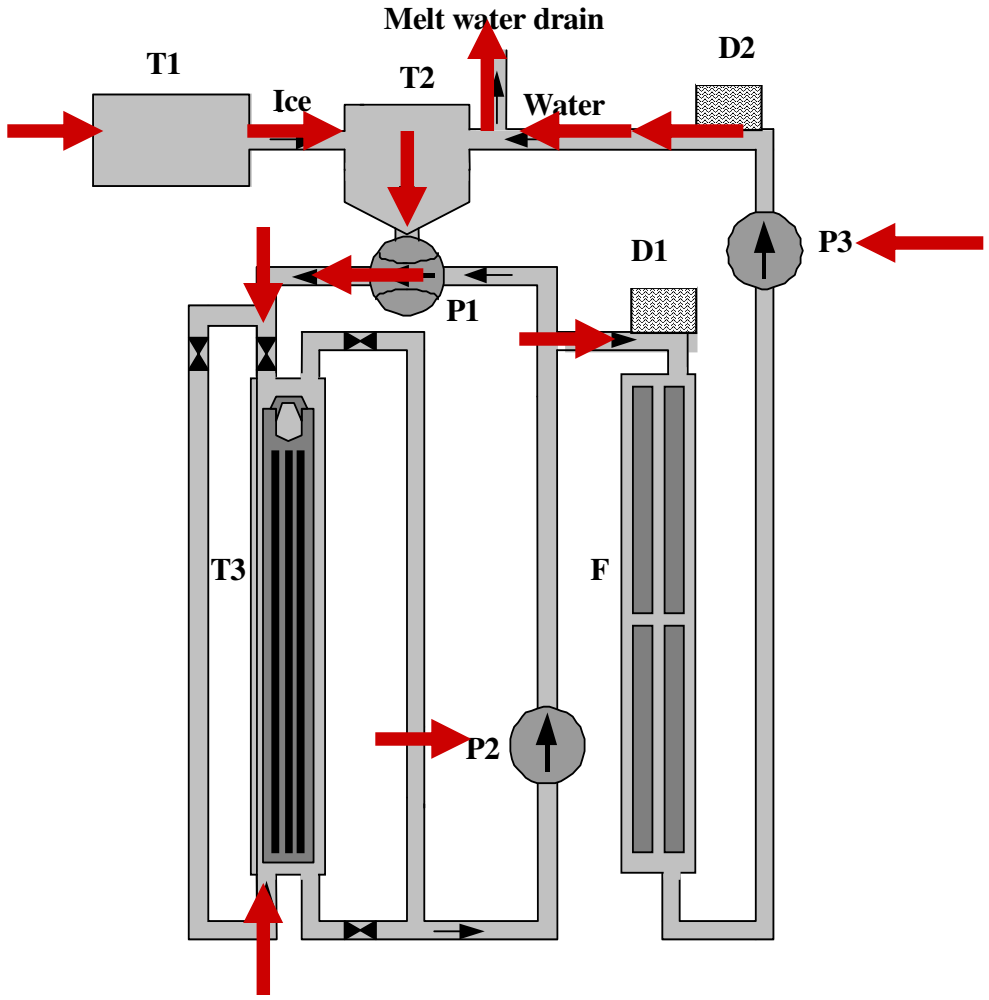
- Full-scale tests of spent fuel 2001
- Decontamination of two year-old fuel 2001
  - ↗The fuel was put back in core for further irradiation

# Criteria

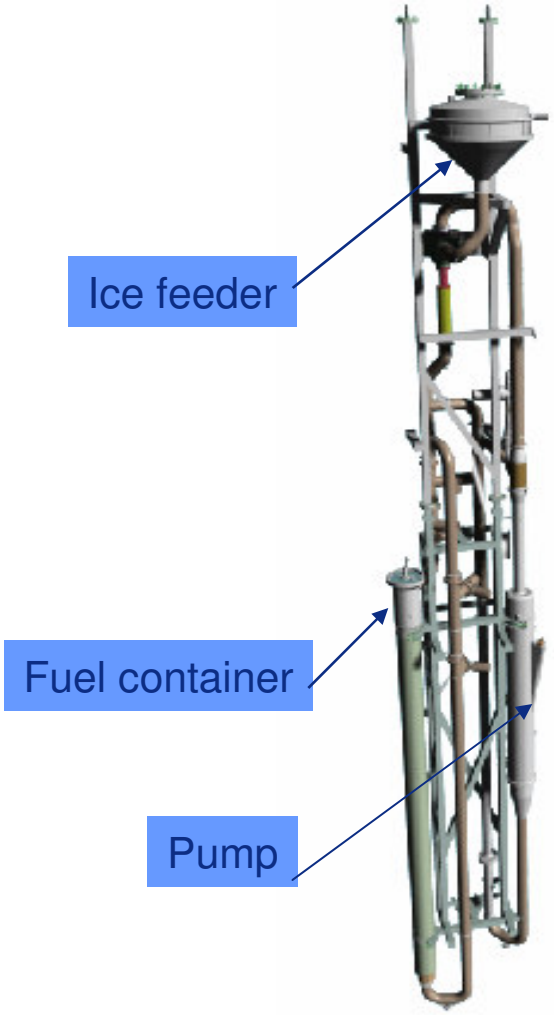
Criteria for development of a fuel decontamination method:

- Remove the fuel crud without risking the fuel integrity.
- The method should be non chemical
- The oxide-layer on the fuel cladding should not be affected.
- Prevent the removed crud from reaching the pool water.

# ICEDEC™ – Sketch of the system



# BWR ICEDEC™

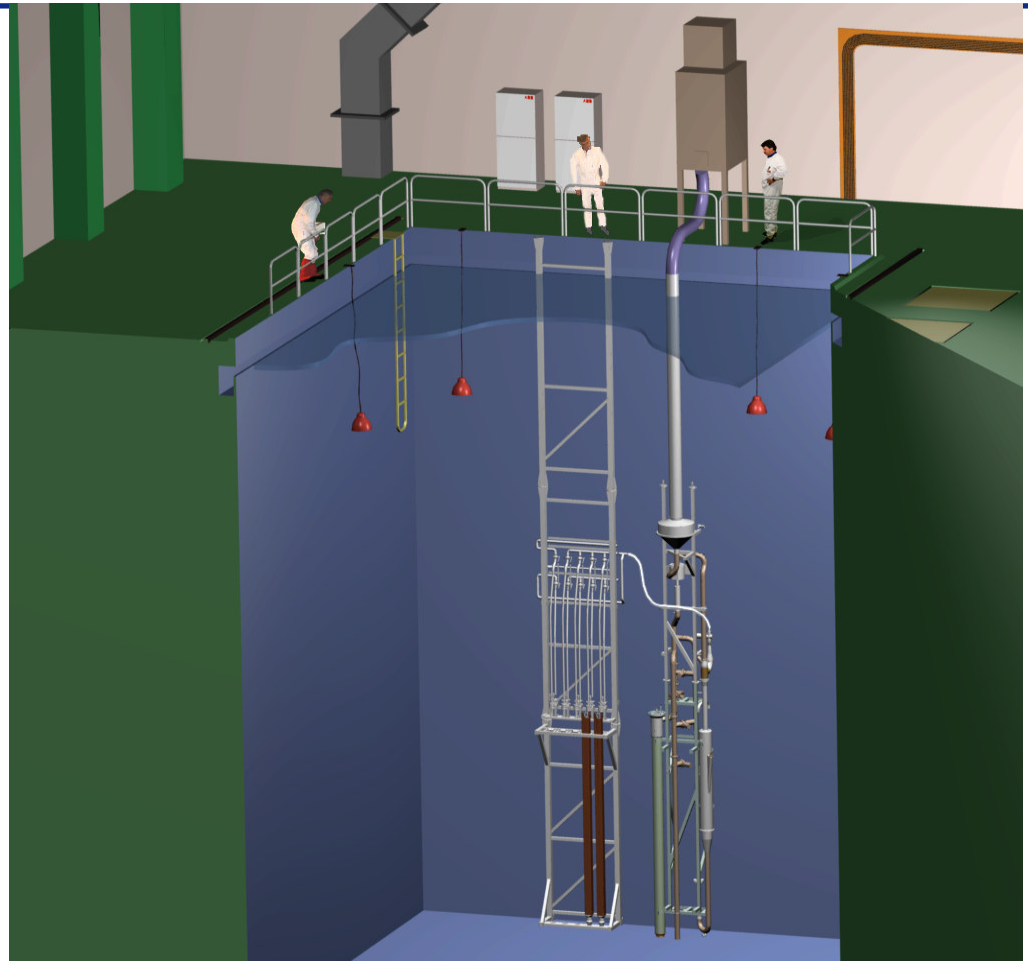



Special filter:

-Dimensions as a BWR fuel assembly

-High radiation resistance

# ICEDEC™



# ICEDEC™ filter unit

- Four parallel filter modules
  - ↗filtering in two steps
    - –two sections each, 10 μm, 1 μm
- One filter module in series with the others
  - ↗0,5 μm
- Outer dimensions as a fuel assembly

- Optional: Ion exchange module
  - ↗Mixed bed resins

# ICEDEC™ filter unit *contd.*

Capacity: 5 kg crud

- Corresponding to approximately 150 two-year-old fuel assemblies (Swedish and Finnish BWR conditions)

# Decontamination tests

Ringhals 1 2001

- Spent fuel (five-year-old)
  - ↗Verification tests

- Two-year-old fuel
  - ↗Decontamination of fuel for further irradiation

# Verification tests

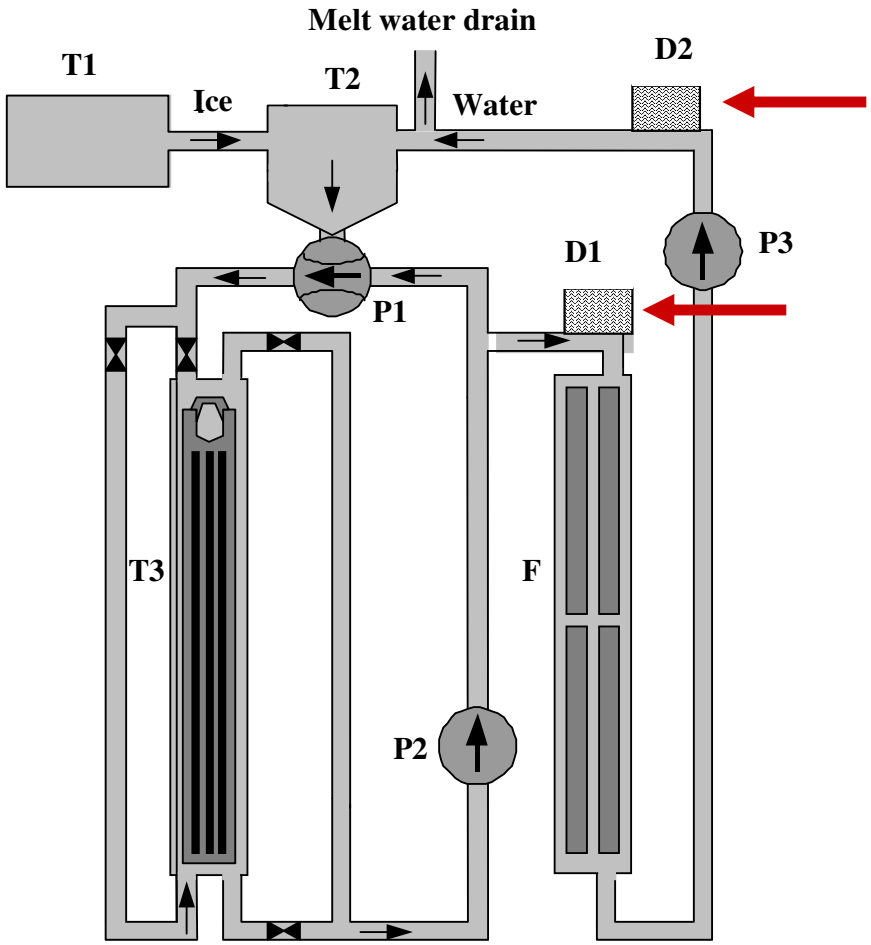
- Procedure, process parameters (flow, pressure…)
- Fuel integrity
  - ↗fuel inspections before and after decontamination
- Filter efficiency
  - ↗gamma scanning
- Decontamination efficiency
  - ↗crud sampling
  - ↗on-line gamma detection
  - ↗gamma scanning

# Decontamination of two-year-old fuel

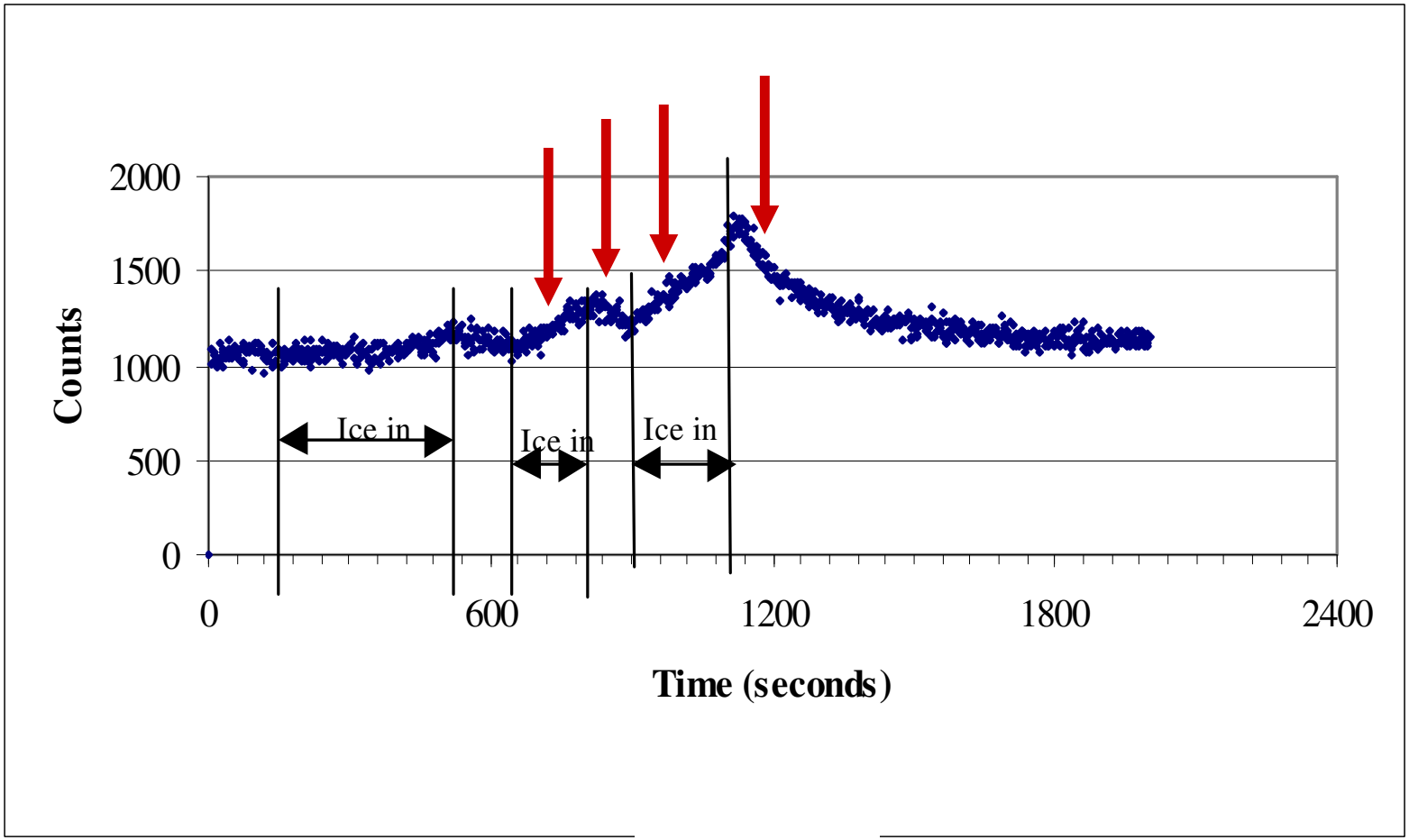
Decontamination at Ringhals 1, June 2001

- Fuel inspection before and after decontamination
- Decontamination efficiency
  - ↗crud sampling
  - ↗on-line gamma detection

# ICEDEC™ – Sketch of the system



# Process verification studies



# Process verification studies *contd.*

- The crud was only removed when ice particles was fed to the fuel assembly
- The decontamination ceased within 10 sec after ice feeding was stopped
  - ↗Easy to manage the decontamination process
- Decontamination and dismounting of equipment free from complications
- Mandoses as for normal fuel services

# Fuel integrity - inspection programme

Fuel inspection - aim

- Visual inspection of sub-assemblies, sub channels
  - ↗mechanical integrity of the fuel
- Gamma scanning
  - ↗spacer displacements
- Oxide thickness measurement
  - ↗depth of the decontamination procedure
- Crud sampling
  - ↗amount of removed crud

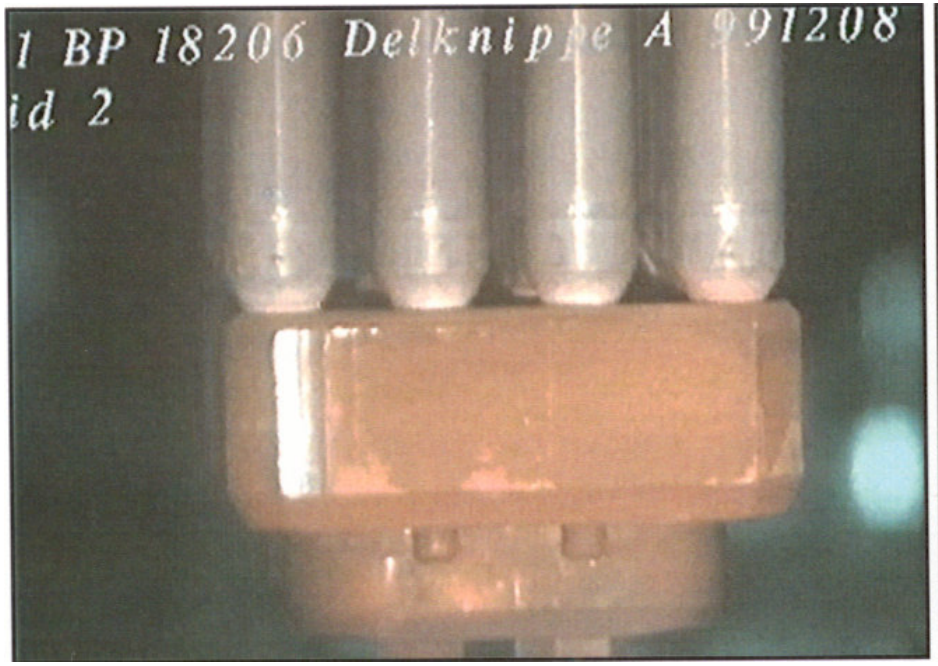
# Results of the fuel inspection

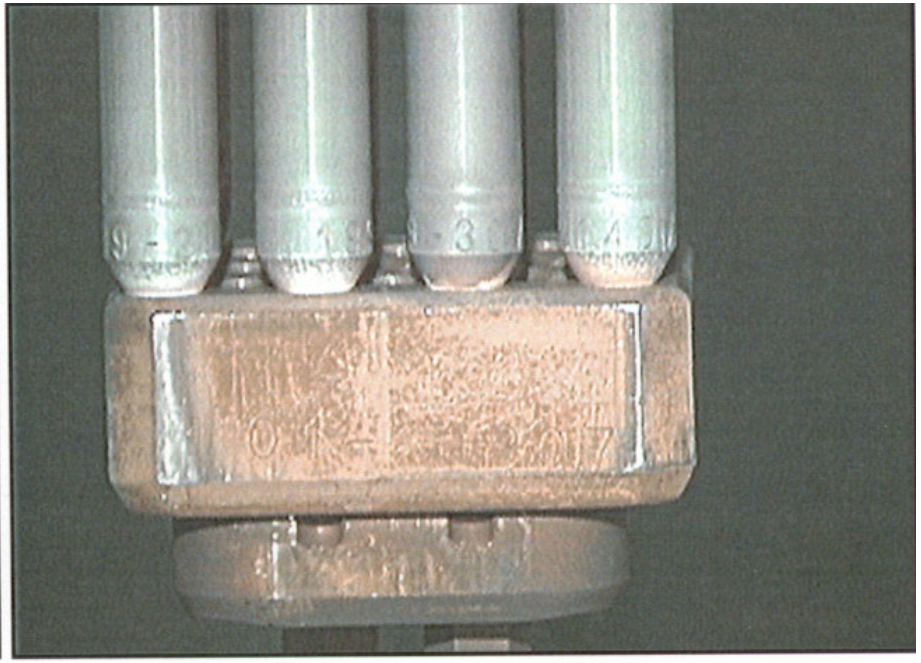
- Details presented at *Jahrestagung Kerntechnique, Annual Meeting on Nuclear Technology, May 2002, Germany*

# Visual inspection

- Normal behaviour both before and after the decontamination
- The rods remained in contact with the bottom tie plate
- All components, such as spacers, compression springs, nuts and tie plates were free from any defects

# Inspection of five-year-old fuel

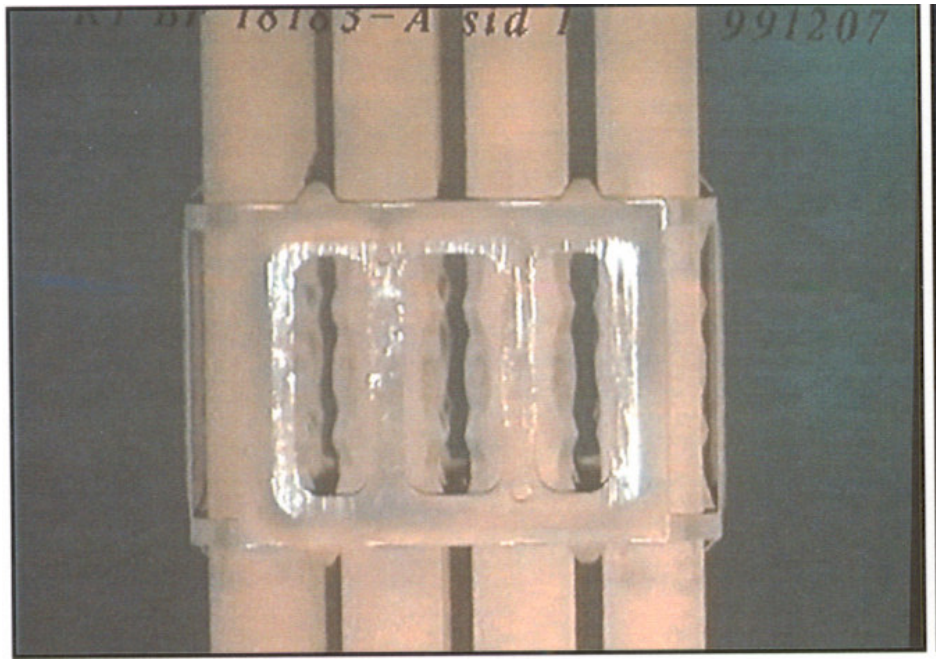


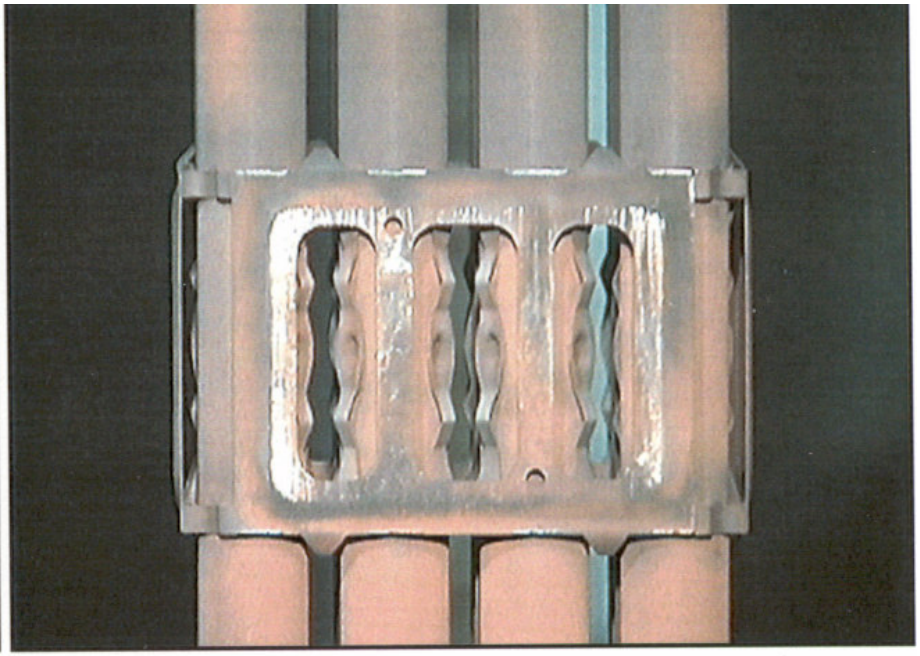
Bottom plate before decontamination

Bottom plate after decontamination

# Inspection of five-year-old fuel *contd.*

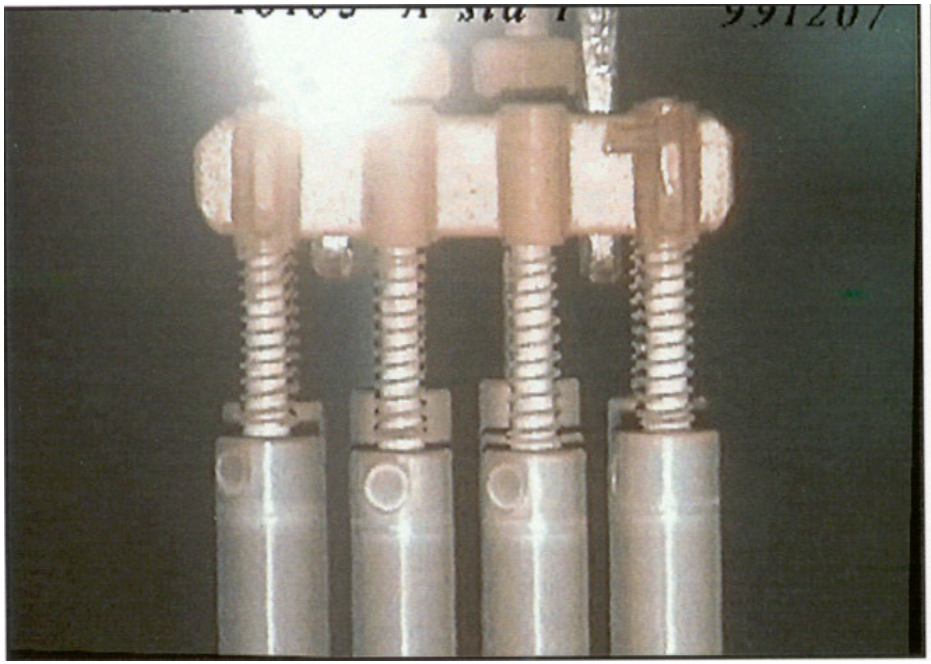


Spacer six before decontamination

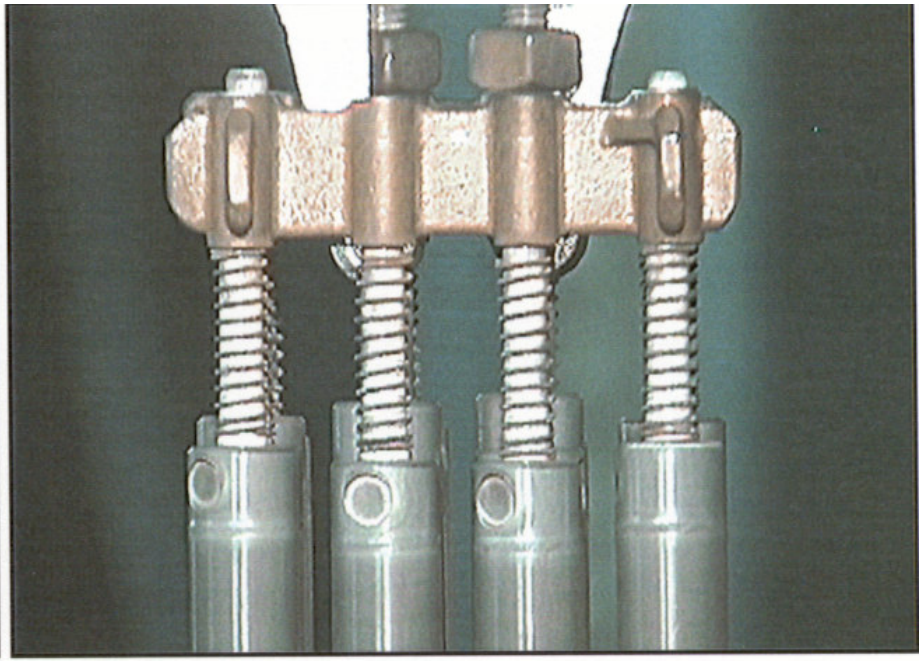


Spacer six after decontamination

# Inspection of five-year-old fuel *contd.*

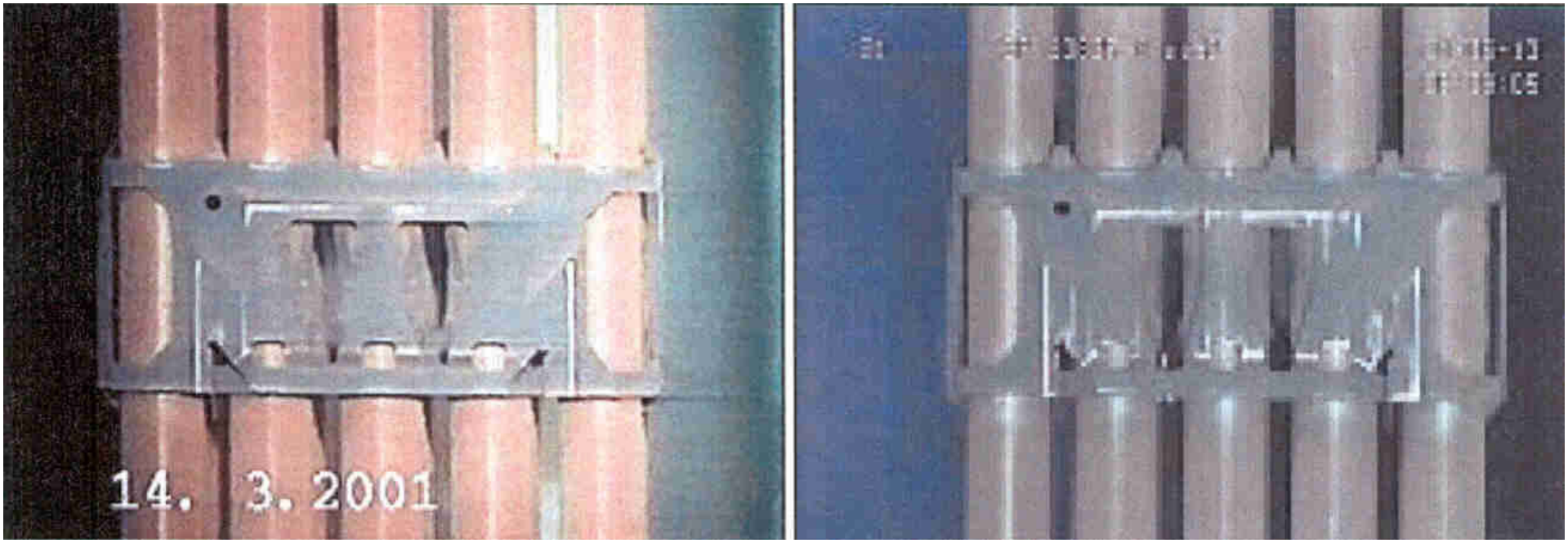


Top plate before decontamination



Top plate after decontamination

# Inspection of two-year-old fuel




Spacer two before decontamination

Spacer two after decontamination

# Oxide measurements

- Only the loose crud was removed - the cladding oxide remained intact

# Crud sampling

Brush and grind (loose and tenacious crud) sampling before and after decontamination - detection of Co-60

- Amount of loose crud:
  - ↗2-year old fuel: 60-65 %
  - ↗5-year-old fuel: 7-9 %
- Decontamination fraction loose crud:
  - ↗2-year-old fuel:  42% (brushing), 46 % (grinding)
  - ↗(5-year-old fuel: 100 %)

# On-line activity

Activity measurements (total gamma activity) of removed activity from the fuel

- Decontamination fraction loose crud
  - ↗2-year-old fuel: 53 %

# Gamma scanning

- Decontamination fraction
  - ↗ difficult to evaluate due to high background radiation
- Possible spacer displacements
  - ↗*Jahrestagung Kerntechnique, Annual Meeting on Nuclear Technology, May 2002, Germany*
- Filter modules
  - ↗> 85 % of the activity originated from Co-60
  - ↗> 80 % of the activity trapped in the 10 μm filter

# Spacer displacements

- Two-year old-fuel: No spacer displacement was shown

- Five-year-old fuel:The lowest spacers had moved upwards to the mechanical stop
  - ↗The first fuel assembly tested before conditions such as flow and pressure had been established
  - ↗Regarded as normal behaviour owing to relaxed spring forces in spent fuel spacers

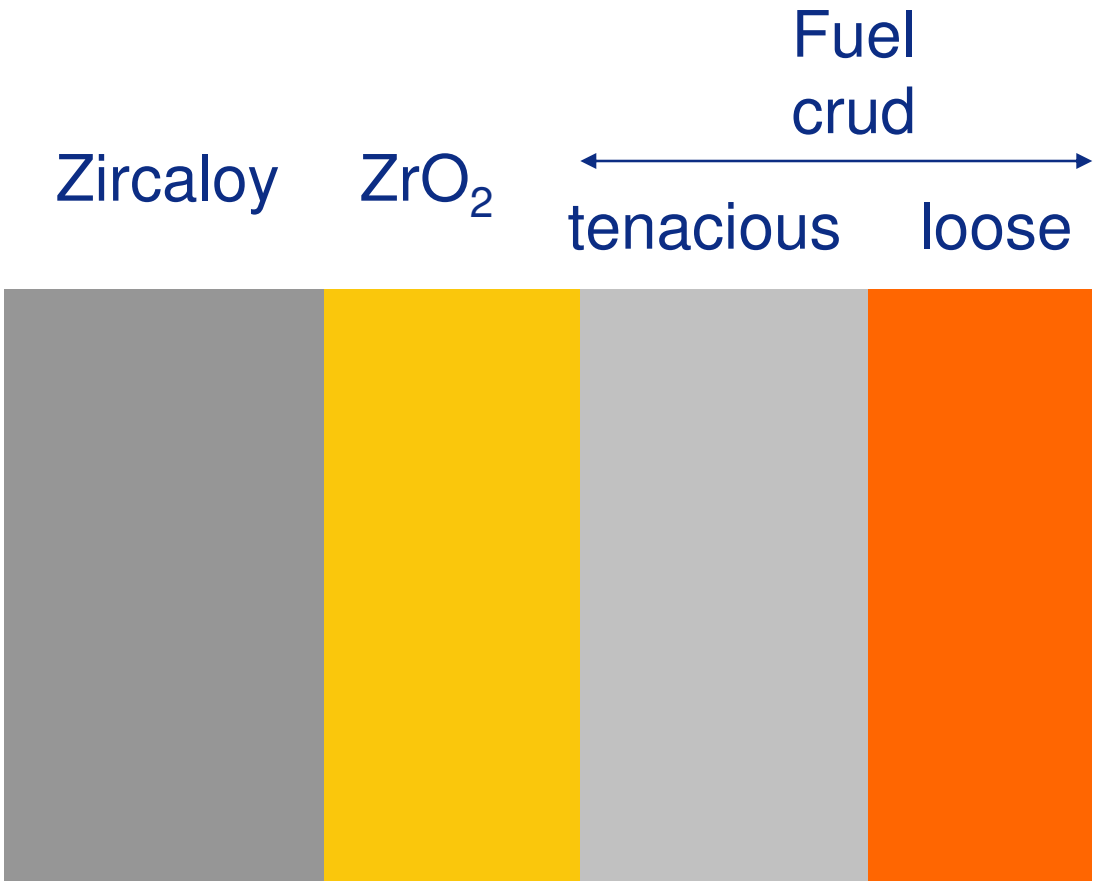
# Filter efficiency

- Water sampling of  circulating water before and after filter unit (Co-60 gamma activity)
  - ↗Efficiency 90-95 %
    - –Colloids and particels < 0,5 μm pass through
  - ↗Highest at high activity

# Decontamination fraction determinations

- Loose crud 2-cycle assembly: 42-53 %
  - Single assembly!
  - Based on definition of loose crud from crud sampling!

# Loose /tenacious crud




What is the ”real” definition of loose crud?

How much of the loose crud is released to the reactor water and thus causing activity build-up?

# ICEDEC™ - Conclusions

- ICEDEC™ maintains the fuel integrity
- Only crud is removed - the oxide remains intact
- No negative effect on the cladding oxide or the mechanical parts of the fuel is obtained
- The contamination process is easy to control
- No higher mandoses than for services during normal refuelling outages

# ICEDEC™ - Goings-on and future

- Discussions with Swedish and US facilities
- Improve  DF
- Improve filter efficiency
- Develop ICEDEC™ for PWR

# Acknowledgement

Former project manager Lennart von der Burg is gratefully acknowledged

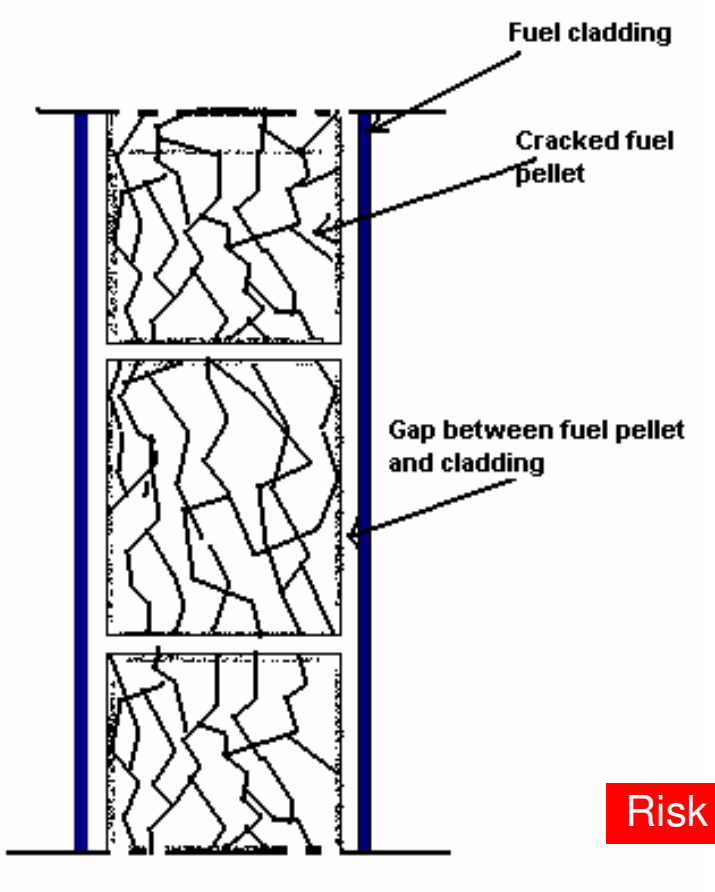
# 2003 International ALARA Symposium

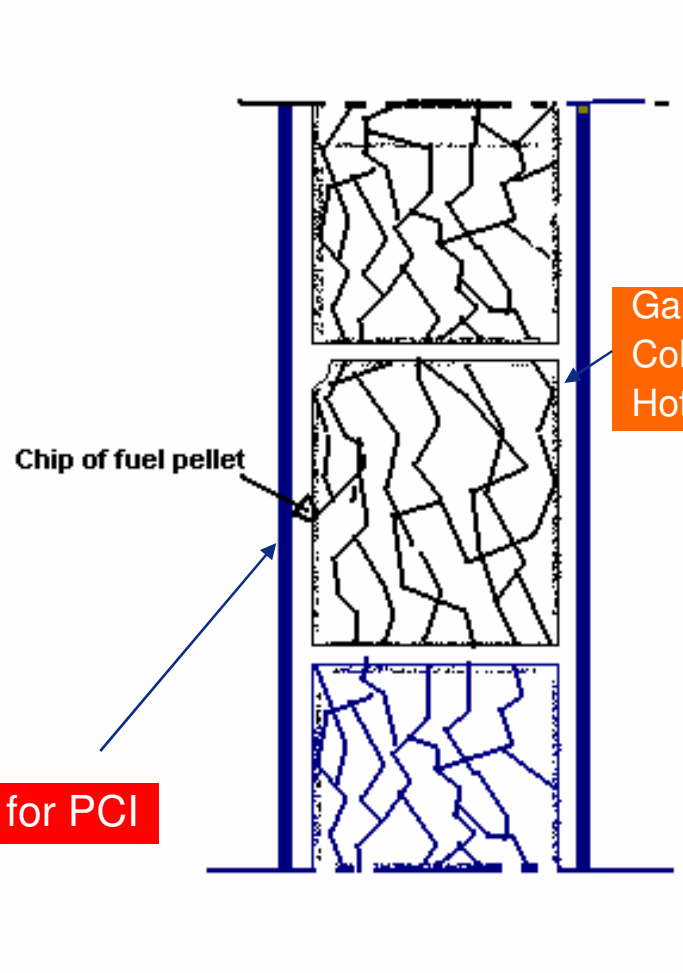
## 3rd EC/IAEA/ISOE Workshop on "Occupational Exposure Management in Nuclear Power Plants"

Portoroz, Slovenia, 17-19 April, 2002

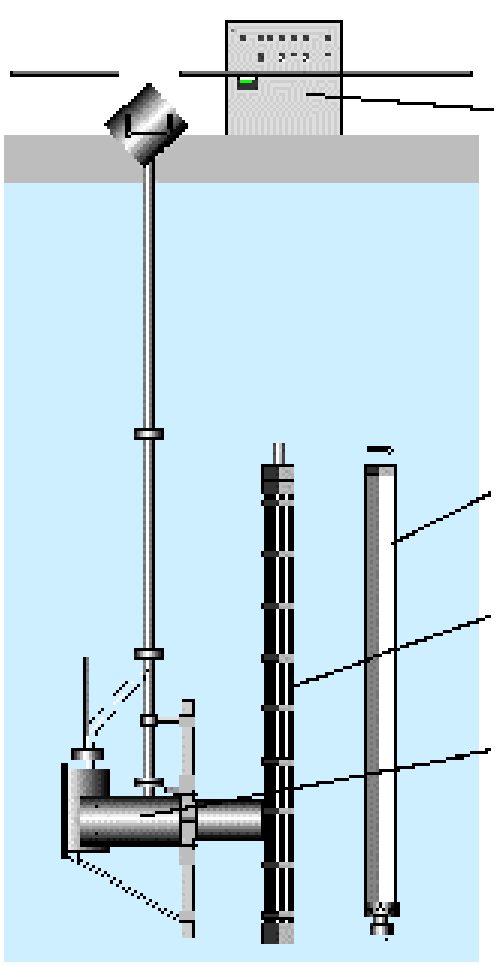
Thank you!!

# Reason for not chosing ultrasonic cleaning



# Gamma scanning equipment



Control unit

BWR fuel assembly

PWR fuel assembly

Detector and collimator housing

# Gamma scanning - spacer displacement

## Measurement of Co-60 along the side of the assembly